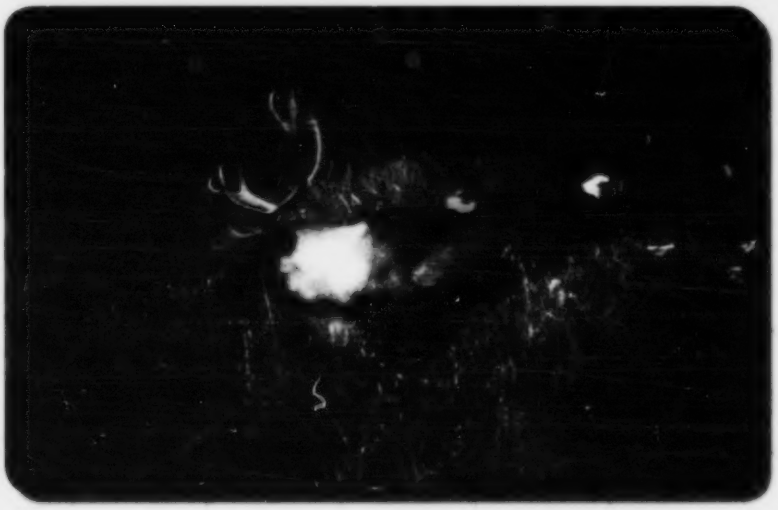
Centre for Northern Forest Ecosystem Research *Information Paper* 002

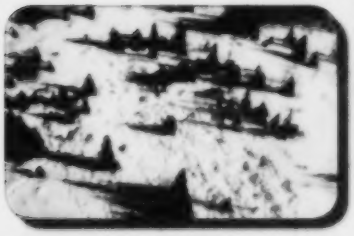
Forest-Dwelling Woodland Caribou in Ontario

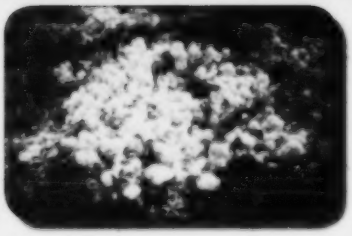
CNFER Experimental Design Workshop Report

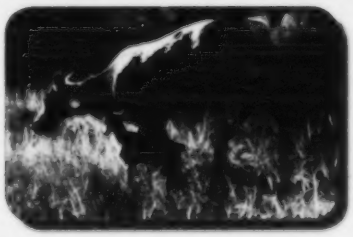
Mississauga, Ontario

November 27 - 29, 2007









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CNFER Experimental Design Workshop Report

Mississauga, Ontario: November 27 - 29, 2007

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EXECUTIVE SUMMARY

The Centre for Northern Forest Ecosystem Research, an applied research section of the Ontario Ministry of Natural Resources, conducted an Experimental Design Workshop for Forest-Dwelling Woodland Caribou Research in Mississauga, Ontario, November 27 – 29, 2007.

The decline in woodland caribou (*Rangifer tarandus caribou*) range occupancy in Ontario has been recognized since the late 1940s and the boreal population of forest-dwelling woodland caribou is designated as "Threatened" both provincially and federally. The need for new research and management of woodland caribou in Ontario has been well documented through published research articles, workshops, advisory committees, summary reports, and independent forest audits. Previously, a comprehensive summary of caribou questions and information needs was compiled from a variety of source documents, including a draft of the Recovery Strategy for Forest-Dwelling Woodland Caribou (*Rangifer tarandus caribou*) in Ontario (February 2005). To identify the most important caribou research issues, the Centre for Northern Forest Ecosystem Research (CNFER) surveyed Ontario Ministry of Natural Resources (OMNR) managers and staff as well as resource industry, non-governmental groups, academic, tourism, federal, and municipal government representatives known to have had involvement or interest in woodland caribou through work on Forest Management Plans, Protected Areas, Species at Risk, policy development, wildlife management, conservation issues, or research.

The key uncertainties identified in the CNFER survey were all related to the direct and indirect effects of disturbance (e.g., by commercial forestry operations, mining, fire) on the occurrence of forest-dwelling woodland caribou in Ontario. Habitat selection at multiple scales and predation were clearly identified as important factors in the most highly ranked caribou research issue, and road and other corridor effects were among the most important subject areas identified for further research. A previous CNFER Forest-Dwelling Woodland Caribou Research Workshop reviewed and refined these issues into rigorous scientific hypotheses in support of preliminary designs for an adaptive management approach to support the conservation of caribou in Ontario. The objective of the CNFER Forest-Dwelling Woodland Caribou Experimental Design Workshop was to further refine active adaptive management experiments to address the primary word models developed in the first workshop and to examine the potential for a woodland caribou research program in central Canada that would coordinate and integrate research activities, establish partnerships, and leverage additional support.

The CNFER Experimental Design Workshop began with a review of progress made and competing models developed during the first workshop. This led to a reconsideration of the probability of caribou persistence as a more effective dependent variable of interest than probability of occurrence. Participants agreed that whereas some key uncertainties might be addressed with occurrence data, it is the probability of persistence determined through collection of vital rates (i.e., mortality/survival, reproduction, immigration, emigration) in a population viability analysis (PVA) that has greater potential to inform an adaptive management approach to support the conservation of caribou in Ontario. The benefits of conducting a PVA based on both field experiments and a combined model simulation/retrospective research design were discussed. Key uncertainties affecting caribou populations (i.e., roads, predation, habitat pattern), derived from competing hypotheses outlined in the first workshop, were used to identify experimental treatment units. Dependent and independent variables related to caribou and the key uncertainties that need to be measured in each treatment unit were detailed. Accessibility of historical data for a model simulation/retrospective study was discussed and it was agreed that a re-examination of previous work should be undertaken. Criteria for the selection of potential treatment areas for field experiments were outlined and the possibility of complementary or additional study sites in Manitoba and Québec was discussed.

The final morning of the meeting began with an assessment of whether or not the treatment units identified were sufficient to address the key uncertainties, particularly with regard to the effects of

forest harvesting. The need to consider caribou re-occupation of disturbed areas and the possibility of a translocation study following the PVA studies was discussed. Potential connections among caribou herds of the forest-dwelling ecotype and with forest-tundra ecotypes were described for Ontario and Québec. Finally, there was a discussion of how to move forward on a coordinated and collaborative research program for woodland caribou that includes a wide range of potential studies that may be undertaken by government agencies, non-government organizations, and university academics, including Québec, Ontario, and Manitoba. A writing team was established to prepare a broad program proposal for woodland caribou research in Ontario that will outline the range of projects needed to inform a long-term adaptive management approach to caribou conservation, and to which individual groups could contribute specific project proposals for integration to the overall program.

An adaptive management program for woodland caribou in Ontario will be a major logistical undertaking. CNFER and other project leaders will continue to pursue partnership opportunities through provincial and federal government and non-government organizations. This research program will make a significant contribution to the attainment of many of the recovery objectives for woodland caribou in Ontario and will provide a basis for the refinement of habitat regulations and management plans as required by the *Endangered Species Act*. Clarification of uncertainties around caribou persistence resulting from this research program will inform revisions and/or modifications to forest management practices and wildlife management policy to meet the objective of keeping forest-dwelling woodland caribou on the Ontario landscape.

SOMMAIRE

Le Centre de recherches sur l'écosystème des forêts du Nord (CRÉFN), une unité de recherche appliquée du Ministère des Richesses naturelles (MRN) de l'Ontario, a organisé un atelier de conception expérimentale de la recherche sur le caribou des bois sylvicole de l'Ontario à Mississauga, en Ontario, du 27 au 29 novembre 2007.

On observe depuis la fin des années 1940 une diminution du taux d'occupation des aires de répartition du caribou des bois (*Rangifer tarandus caribou*) en Ontario. Les gouvernements provincial et fédéral ont désigné la population boréale du caribou des bois sylvicoles une « espèce menacée ». L'importance de mener d'autres études et de gérer efficacement le caribou des bois de l'Ontario a été soulignée dans des articles de recherche publiés, lors d'ateliers, par des comités consultatifs, dans des rapports sommaires et à la suite de vérifications indépendantes de forêts. Un résumé global des questions entourant le caribou et des besoins en information connexe en se fondant sur divers documents sources, y compris une ébauche de la *Stratégie de rétablissement de la population sylvicole de caribous des forêts* (Rangifer tarandus caribou) *en Ontario* (février 2005), avait été publié. Pour déterminer les principales questions relatives à la recherche sur le caribou, le CRÉFN a mené un sondage auprès de gestionnaires et d'employés du MRN, ainsi qu'auprès de l'industrie primaire, d'organisations non gouvernementales, d'universités, du secteur du tourisme et de représentants du gouvernement fédéral et d'administrations municipales qui ont un intérêt pour le caribou des bois ou qui ont déjà participé à des projets connexes, tels que des projets de gestion des forêts, de création de zones protégées, de rétablissement d'espèces en péril, d'élaboration de politiques, d'aménagement de la faune, de conservation ou de recherche.

Les principales incertitudes soulevées dans le cadre du sondage du CRÉFN portaient sur les effets directs et indirects des perturbations (p. ex. activités forestières commerciales, exploitation minière, incendies) sur la présence du caribou des bois sylvicole en Ontario. La sélection d'habitats à échelles multiples et la prédation sont clairement perçues comme d'importants facteurs de la plus importante question de recherche sur le caribou, et l'incidence des routes et d'autres types de corridors, comme étant quelques uns des sujets requerrant plus de recherches. Au cours de l'un de ses ateliers de

conception expérimentale de la recherche sur le caribou des bois sylvicole de l'Ontario précédents, le CRÉFN a examiné et transformé ces questions en hypothèses scientifiques rigoureuses pour appuyer les premières conceptions d'une approche de gestion adaptative de la conservation du caribou en Ontario. L'objectif de l'atelier était d'améliorer encore plus les essais de gestion adaptative active en réponse aux premiers modèles élaborés lors du premier atelier, ainsi que d'examiner la possibilité de mettre en œuvre un programme de recherche sur le caribou des bois dans le Canada central, qui permettrait de coordonner et d'intégrer les activités de recherche, de créer des partenariats et d'obtenir plus d'appui.

L'atelier de conception expérimentale du CRÉFN a débuté par un examen des progrès réalisés et des modèles concurrents élaborés durant le premier atelier. Ceci a mené au réexamen de la probabilité de persistance du caribou comme variable dépendante plus fiable que la probabilité d'occurrence. Les participants estiment que même si quelques unes des incertitudes clés peuvent être traitées à l'aide de données sur l'occurrence, la probabilité de persistance, déterminée en tenant compte d'un ensemble d'indices vitaux (mortalité/survie, reproduction, immigration, émigration) dans le cadre d'une analyse de la vitalité de la population, devrait fournir davantage d'information pour l'élaboration d'une approche de gestion adaptative de la conservation du caribou en Ontario. Les avantages de l'analyse de la vitalité de la population fondée sur des expériences sur le terrain, ainsi que la conception d'exercices de simulation/ de recherches rétrospectives ont fait l'objet de discussions. Les principales incertitudes concernant les populations de caribou (p. ex. les routes, la prédation, la répartition des habitats), déterminées à partir d'hypothèses concurrentes présentées au premier atelier, ont servi à cerner les unités de traitement expérimental. Les variables dépendantes et indépendantes liées au caribou et les principales incertitudes qui doivent être évaluées dans chaque unité de traitement ont été présentés en détail. L'accès aux données historiques des exercices de simulation/de l'étude rétrospective a été examiné et il a été convenu de procéder au réexamen des travaux précédents. Les critères de sélection des zones de traitement éventuelles d'expériences sur le terrain ont été décrits et la possibilité d'utiliser des sites d'études complémentaires ou supplémentaires au Manitoba et au Québec a également été envisagée.

La dernière journée de la réunion a débuté en se demandant si les unités de traitement déterminées suffisaient pour lever les incertitudes clés, en particulier en ce qui concerne les effets de l'exploitation forestière. Le besoin d'examiner le retour du caribou dans les aires de répartition et la possibilité de mener une étude de translocation à la suite des analyses de la vitalité de population ont fait l'objet de discussions. Les liens éventuels entre les hardes de caribous de bois de l'écotype forestier et avec les écotypes de la toundra forestière de l'Ontario et du Québec ont été décrits. Finalement, des discussions ont été menées sur la façon de promouvoir un programme de recherche coordonnée et collaborative sur le caribou des bois qui comprend une vaste gamme d'études qui seraient éventuellement réalisées par des organismes gouvernementaux, des organisations non gouvernementales et des universitaires, y compris le Québec, l'Ontario et le Manitoba. Une équipe de rédacteurs à été formée pour élaborer une proposition de programme de recherche sur le caribou des bois en Ontario, qui exposera à grands traits les divers projets nécessaires pour obtenir l'information sur laquelle sera fondée l'approche de gestion adaptative à long terme de la conservation du caribou et pour laquelle les différents groupes pourraient fournir des propositions de projets spécifiques pouvant être intégrés à l'ensemble du programme.

Un programme de gestion adaptative du caribou des bois de l'Ontario constituera un projet logistique d'envergure. Le CRÉFN et d'autres chefs de projets continueront de saisir des occasions de partenariats par l'entremise des gouvernements provincial et fédéral et des organisations non gouvernementales. Le programme de recherche contribuera de façon importante à l'atteinte de nombreux objectifs de rétablissement du caribou des bois en Ontario et jettera les fondements de la mise au point des règlements sur l'habitat et des plans de gestion, comme l'exige la *Loi sur les espèces en voie de disparition*. La levée des incertitudes entourant la persistance du caribou à la suite de l'exécution du programme de recherche orientera les changements ou modifications aux pratiques de gestion des forêts et à la politique de gestion de la faune de façon à atteindre l'objectif de garder le caribou des bois sylvicole dans le paysage ontarien.

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The Centre for Northern Forest Ecosystem Research would like to thank Dr. Jim Baker (Science Business Coordinator, OMNR Applied Research and Development Branch), Dr. Jim Schaefer (Associate Professor, Trent University), Dr. Tom Nudds (Professor, University of Guelph), Dr. John Fryxell (Professor, University of Guelph), Dr. Ian Thompson (Research Scientist, Canadian Forest Service), and the workshop facilitator, Lorne Greig (ESSA Technologies Ltd.), for their input and suggestions in developing the workshop, as well as their helpful comments in completing this workshop report.

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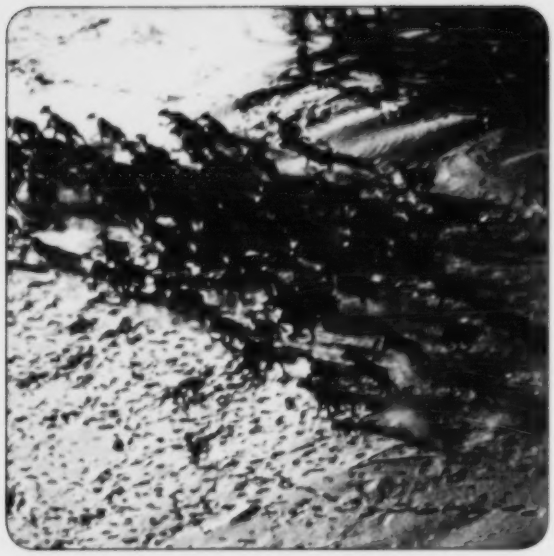
INTRODUCTION

The need to address key uncertainties regarding the persistence of woodland caribou (*Rangifer tarandus caribou*) in Ontario has been well documented through published research articles, workshops, advisory committees, summary reports, and independent forest audits. Media reports and campaigns across Canada by a variety of environmental organizations have heightened public perception about the importance of woodland caribou as an indicator of the health of the boreal forest. The decline in woodland caribou range occupancy in Ontario has been recognized since the late 1940s and the boreal population of forest-dwelling woodland caribou is designated as "Threatened" both provincially (COSSARO 2005) and federally (COSEWIC 2002). Future economic development activities in northern Ontario involving roads, forestry, mining, and hydro development, as well as potential effects of natural disturbance (fire, insect outbreak) and weather (precipitation, temperature), mediated by climate change, could all influence the persistence of woodland caribou. These threats obviate the need for imminent research to provide for the refinement of habitat regulations and management plans under the provincial *Endangered Species Act* (LAO 2007) and a comprehensive caribou conservation plan that will contribute effectively to the nationwide recovery effort (Environment Canada 2007) developed under the federal Species at Risk Act (2002).

The Centre for Northern Forest Ecosystem Research (CNFER), located in Thunder Bay, is an applied research section of the Ontario Ministry of Natural Resources (OMNR). With many pressing issues related to forest-dwelling woodland caribou and a variety of potential directions to focus research, a comprehensive summary of caribou questions and information needs was compiled in November 2005 as part of the Northern Mammal Ecology Program at CNFER. Scientific and technical questions about woodland caribou ecology and management in Ontario were consolidated from a variety of source documents (Table 1) and grouped into 9 broad areas of scientific enquiry: (1) Population management, dynamics and status, ecological dynamics; (2) Land use planning / policy and management; (3) Habitat: critical and core, forage, distribution and fire; (4) Forest management regimes and plans (FMPs), disturbance and techniques; (5) Genetics and metapopulations; (6) Predator/prey dynamics; (7) Recruitment, survival, mortality, population limiting factors, cumulative impacts; (8) Road and other corridor effects; and (9) Inventory, monitoring and reporting. An initial list of 91 questions was refined to a final list of 42 by including only those questions that could be undertaken in a research program at CNFER, given its mandate and current expertise. Excluded questions involved research currently underway (e.g., genetic studies through the DNA Profiling and Forensic Centre at Trent University) or that may be undertaken by another unit within the OMNR (e.g., determination

Table 1. Sources of research questions used in the development of the CNFER - Forest-Dwelling Woodland Caribou Research Survey.

Author	Year	Document
Ontario Woodland Caribou Recovery Team (W. J. Rettie, editor)	Feb-05	Recovery Strategy for Forest Dwelling Woodland Caribou in Ontario, Draft.
J. Chikoski, H. Gignac	Feb-05	Caribou Technical Workshop summary, OMNR.
OMNR	2004a,b	Strategy for Wolf Conservation in Ontario and Backgrounder on Wolf Conservation In Ontario.
T. J. Chowns	Aug-03	State of the Knowledge of Woodland Caribou in Ontario, Report for Forestry Research Partnership.
Ontario Woodland Caribou Advisory Committee	Oct-02	Minutes of the Meeting.
A. Harris	Jun-99	Report on the Status of Woodland Caribou in Ontario, COSSARO Report.
K. M. Brown	Apr-99	Planning the next Round of Caribou Habitat Research, Workshop Proceedings.



of population size by the Inventory, Monitoring, and Assessment Section). Nonetheless, these additional research and monitoring studies may be closely linked with questions potentially addressed by a CNFER research program.

The final list of 42 questions, grouped by subject area, was used to develop a survey that was distributed internally to OMNR staff who had involvement or interest in woodland caribou through work on Forest Management Plans, Protected Areas, Species at Risk, policy development or wildlife management, and externally to federal government colleagues, non-governmental individuals and university academics with interests in caribou. The survey was sent to a total of 262 individuals. Survey participants were asked to rate and rank the relative importance of the 9 subject areas, as well as the general and specific research questions within each, according to their perceived level of importance. They were then asked to select and rank the 3 most important research questions in the survey, regardless of subject area.

The 3 most important subject areas identified for further research in the CNFER survey were: (1) Forest management regimes and plans (FMPs), disturbance and techniques; (2) Land use planning / policy and management; and (3) Road and other corridor effects. There was also strong interest in additional research on (4) Population management, dynamics and status, ecological dynamics and (5) Recruitment, survival, mortality, population limiting factors, cumulative impacts. The most important caribou research issue, regardless of subject area, identified by both OMNR and external respondents was:

> *Evaluate effects of landscape disturbances created by commercial forestry operations on caribou populations (via individual caribou survival and mortality causes, recruitment, habitat selection at multiple scales, measuring changing abundance of moose, deer and predation by wolves and bears).*

Secondary research issues identified as important in the survey were:

> *Determine the mechanisms driving forest woodland caribou population dynamics in modified landscapes, and*
>
> *At what level of disturbance do caribou abandon previously occupied habitat (threshold of disturbance)?*

To refine these research issues into rigorous scientific hypotheses and to formulate alternative experimental designs for their examination, a Forest-Dwelling Woodland Caribou Research Workshop was held at the Kempenfelt Centre in Barrie, Ontario, October 31 – November 2, 2006 (Rodgers et al. 2007). The workshop began with a series of presentations, including several from

neighbouring jurisdictions (i.e., Alberta, Manitoba, and Québec), to provide context for the design of future caribou research in Ontario. Principles of Decision Analysis and Adaptive Management (Jones and Nudds 2003) were subsequently used to guide further program development. Workshop participants were assigned to 4 autonomous working groups that each identified dependent and independent variables, the quality and availability of necessary data, and generated "word models" based on competing hypotheses regarding the key uncertainties affecting caribou populations. Twenty-three dependent and 44 independent variables were identified. The most often listed and important dependent variable was probability of occurrence, and all groups selected at least one independent variable related to each of roads, predation, and habitat pattern. Working groups assessed the spatial and temporal scales required to evaluate the models under each of 3 experimental options: model simulation, retrospective analysis, and field experiments. Spatial and temporal scales of experimental design varied from 3,000 km^2 to over 100,000 km^2 and from 5 to 50 years, respectively.

The general word models/hypotheses and initial designs for adaptive management developed during the CNFER Research Workshop address the most important caribou research issues identified in the CNFER survey: the probability of forest-dwelling woodland caribou occurrence is likely a function of some combination of roads (density, use and/or type), predation (predator density, predation rate, and prey biomass or abundance, including alternative prey), and habitat pattern (disturbance type, composition, and patch size) best addressed at multiple spatial scales with an Active Adaptive Management approach that includes spatial controls for those factors.

The objective of the CNFER Forest-Dwelling Woodland Caribou Experimental Design Workshop was *to further refine Active Adaptive Management experiments to address the primary word models developed in the first workshop and to examine the potential for a woodland caribou research program in central Canada* that would coordinate and integrate research activities, establish partnerships, and leverage additional support. The ultimate goal of this research program is to provide advice for the recovery and long-term maintenance of forest-dwelling caribou in Ontario.

WORKSHOP OVERVIEW

An initial agenda for the CNFER Woodland Caribou Experimental Design Workshop and a list of potential facilitators and participants was developed in August 2007 by Ed Iwachewski (Manager, CNFER), Art Rodgers (Research Scientist, CNFER), Brad Allison (Research Biologist, CNFER), and Keith Wade (Project Biologist, CNFER) with input and suggestions from Jim Baker (Science Business Coordinator, OMNR Applied Research and Development Branch), Jim Schaefer (Associate Professor, Trent University), Tom Nudds (Professor, University of Guelph), John Fryxell (Professor, University of Guelph), and Ian Thompson (Research Scientist, Canadian Forest Service). Lorne Greig, ESSA Technologies Ltd., was contracted to facilitate the first day-and-a-half of the Experimental Design Workshop and Ed Iwachewski facilitated the final day's discussions of an integrated central Canada woodland caribou research program. Workshop participants (Appendix) were drawn from invitees to the first CNFER Research Workshop. Including the facilitators, 24 participants attended the CNFER Woodland Caribou Experimental Design Workshop held at the Delta Toronto Airport West Hotel in Mississauga, Ontario, November 27 – 29, 2007. Although the Experimental Design Workshop did not strictly adhere to the original sequence, all of the subject areas included in the preliminary agenda (Table 2) were discussed during the 2-day meeting.

Table 2. Preliminary CNFER Woodland Caribou Experimental Design Workshop Agenda, November 27 – 29, 2007.

Day/Session	Time	Activity/Title	Presenter(s)/Lead(s)
Tuesday, Nov. 27			
Welcome/Introduction	1:00	Day 1 Objectives	Lorne Greig (Facilitator)
Background/Moving Ahead	1:15	Summary & conclusions of 2006 CNFER Research Workshop & next steps	Art Rodgers/Tom Nudds
Session I	1:45	Development of competing models from key uncertainties and word models/hypotheses	Lorne Greig (Facilitator)/All
BREAK	3:00		
Session I (cont.)	3:30	Competing models	Lorne Greig (Facilitator)/All
END DAY 1	5:00	Day 1 Summary	Lorne Greig (Facilitator)
Wednesday, Nov. 28			
Session II	8:30	Day 2 Objectives	Lorne Greig (Facilitator)
Session II (cont.)	8:45	Identification of "treatments" & "controls"	Lorne Greig (Facilitator)/All
BREAK	10:15		
Session II (cont.)	10:30	Replication of treatments (number and geographic distribution)	Lorne Greig (Facilitator)/All
LUNCH	12:00		
Session II (cont.)	1:00	What needs to be measured (dependent and independent variables)	Lorne Greig (Facilitator)/All
Session II (cont.)	2:00	Measurement techniques & sample size requirements	Lorne Greig (Facilitator)/All
BREAK	3:00		
Session III	3:30	Revisit research designs: comparative vs manipulative & retrospective vs modeling vs field experiments	Lorne Greig (Facilitator)/All
END DAY 2	5:00	Conclusions	Lorne Greig (Facilitator)/Art Rodgers
Thursday, Nov. 29			
Session IV	8:30	Introduction to Caribou Conservation Plan	Ed Iwachewski (Facilitator)
Session IV (cont.)	8:45	Forest-tundra & forest-dwelling woodland caribou connectivity	Ken Abraham
Session IV (cont.)	9:00	Genetics and condition of three caribou ecotypes in Québec-Labrador	Serge Couturier
Session IV (cont.)	9:15	Forest-dwelling woodland caribou PVA model	John Fryxell
Session IV (cont.)	9:30	Projects, proposals and research interests	Ed Iwachewski (Facilitator)/All
BREAK	10:00		
Session IV (cont.)	10:15	Projects, proposals and research interests	Ed Iwachewski (Facilitator)/All
Session IV (cont.)	11:15	Potential research framework approaches	Ed Iwachewski (Facilitator)/All
Summary and Next Steps	12:00	Workshop wrap-up	Art Rodgers/ Ed Iwachewski (Facilitator)

BACKGROUND AND MOVING AHEAD

Background

The CNFER Woodland Caribou Experimental Design Workshop opened with a review of progress made and competing models developed during the first CNFER Research Workshop (Rodgers et al. 2007). A key element of the first workshop was the acceptance of policy as hypothesis and management by experiment (Lancia et al. 1996). This adaptive management approach will allow determination of the effectiveness of emulating natural disturbance patterns through forest practices, as embodied by the *Crown Forest Sustainability Act* (LAO 1994), and provincial wildlife management policies and legislation, including the *Endangered Species Act* (LAO 2007), in meeting the objective of maintaining forest-dwelling woodland caribou on the Ontario landscape.

To evaluate the extent to which forest practices, conducted under a policy of natural disturbance emulation, and wildlife management policies might achieve the objective of sustaining woodland caribou, key uncertainties need to be expressed as competing models. Participants in the first CNFER workshop generally agreed that the probability of forest-dwelling woodland caribou occurrence was likely to be some function of roads (density, use and/or type), predation (predator density, predation rate, and prey biomass or abundance, including alternative prey), and habitat pattern (disturbance type, composition, and patch size) at multiple spatial scales (Rodgers et al. 2007). Refinement of this general word model/hypothesis into a subset of competing models, providing details of the experimental design (e.g., treatments, measurements, replicates), and consideration of criteria to be used in the identification of potential study areas were the major tasks to be completed in the Experimental Design Workshop.

Occurrence vs. Persistence

Participants in the Experimental Design Workshop suggested research efforts should focus on probability of caribou persistence. Estimating persistence is more difficult than estimating occurrence, but probability of persistence has greater potential to inform management decisions that could maintain woodland caribou on the landscape: enlarging the scope from probability of occurrence to probability of persistence opens up the opportunity to better evaluate the risk of extinction in dynamic terms not possible with "static" models (e.g., Habitat Suitability Index or Resource Selection Function models) or environmental niche monitoring techniques. More specifically, probability of persistence determined through collection of information on vital rates (i.e., mortality/survival, reproduction, immigration, emigration) in a population viability analysis (PVA) can facilitate the development of spatially structured stochastic models that can be used to project changes in the probability of caribou extinction in response to various key uncertainties through time (e.g., Figure 1). Because these models incorporate variability in response to key uncertainties, they provide a range of expectations, including extinction thresholds, which can be managed or planned for. By looking at different combinations of key uncertainties (i.e., competing models), the potential effects of various policy options on caribou extinction risk can be evaluated and the need for new policy development to support the conservation of caribou in Ontario can be determined.

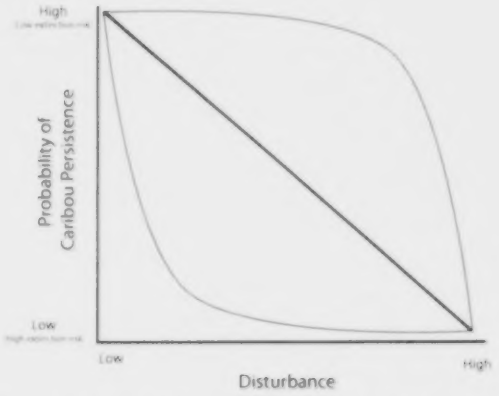


Figure 1. An extinction probability graph showing 3 potential responses of woodland caribou persistence to anthropogenic disturbance (e.g., road density).

The persistence of caribou in Ontario depends on factors that affect vital rates and thus, ultimately, their distribution. Some of these factors may be the same as those that have contributed to their current pattern of occurrence (i.e., roads, predation, multi-scale habitat pattern) but some new factors may come into play (e.g. climate change). An understanding of historic landscape dynamics in relation to past and current caribou distribution will aid in predicting future occurrence. Whereas probability of persistence requires vital rates analysis, probability of occurrence can largely be determined from associations with habitat variables and landscape dynamics, modelled as Resource Selection Functions (RSFs). These RSFs can assist in the design of demographic studies to generate PVA models and better understand caribou persistence under various policy options. In addition, development of RSF models from historic occurrence data may allow some caribou management objectives to be met on the short term. In the longer term, since occurrence is a measure of probability of persistence, occurrence data may be used to evaluate the performance of PVA models in predicting caribou persistence throughout the province.

In the end, participants agreed that a research program for forest-dwelling woodland caribou in Ontario should attempt to understand their current distribution through the development of RSFs using historical occurrence data, and then use that information in conjunction with vital rates studies to generate PVA models and better comprehend caribou persistence under various policy options. Linking PVA models with policy options will benefit short term (2-5 years) policy decisions that must be made by the OMNR for FMPs and as part of Far North planning. Consideration of potential policy options assists in setting the context for adaptive management in terms of explicit "policy as hypothesis" statements. Policy options could include identifying new protected areas and/or expansion of current protected areas, changes to FMPs for locations of harvest and roads, type of silviculture, reductions in wolf populations, and reductions in moose and deer populations.

Population Connectivity

An important aspect of caribou persistence in Ontario is the potential importance of connectivity between populations of forest-dwelling and forest-tundra ecotypes, and the degree of potential population substructure among forest-dwelling caribou. Forest-dwelling caribou are regarded as sedentary and are distinguished from the migratory forest-tundra ecotype by their more limited movements and the dispersion, rather than aggregation, of adult females during calving (Bergerud 1988, 1996). Whereas forest-tundra caribou typically give birth and spend the summer on the tundra and overwinter in coniferous forests, forest-dwelling caribou live year-round in mature coniferous forests and peatlands further south. Approximately three-quarters of the caribou in Ontario are of the migratory forest-tundra ecotype, most belonging to the Pen Islands herd, but the majority of caribou range is occupied by sedentary forest-dwelling populations occurring at very low densities (Cumming 1998, COSEWIC 2002). As the potential importance of exchange between populations of these caribou ecotypes was not explicitly discussed during the first CNFER Research Workshop and is essential to the development of a research program to estimate the probability of persistence for forest-dwelling woodland caribou in Ontario, two presentations were provided during the Experimental Design Workshop, the first by Ken Abraham for Ontario and the other by Serge Couturier for Québec.

Ken Abraham: Status of Woodland Caribou in the Hudson Bay Lowland

Ken Abraham emphasized the need to update our information on the northern forest-tundra caribou herd. He emphasized the plasticity in the distribution and movements of the Pen Island herd and suggested a need to re-evaluate the current distribution, migratory patterns, calving sites, etc., and to address the reason for observed changes. Ken proposed to determine population sizes, identify subpopulations, and to document movements, habitat use, calving sites, and wintering areas of forest-tundra woodland caribou in the Hudson Bay Lowlands (Figure 2) as a means to address this lack of information. He suggested the need to assess winter road activities, particularly in association with new roads, and aboriginal harvesting, which may have long-term consequences for persistence, in addition to an assessment of vegetative habitat condition and predator populations.

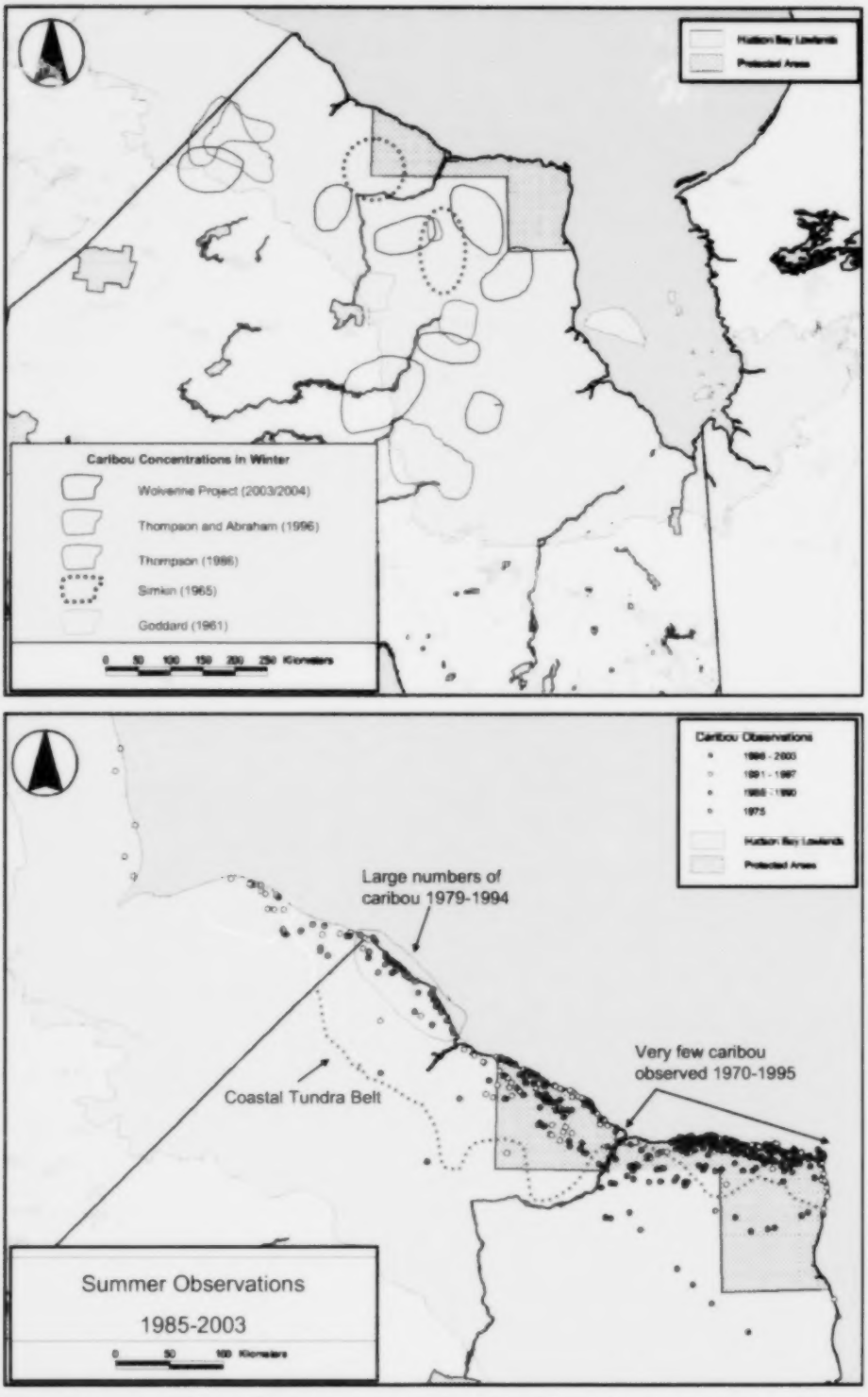


Figure 2. Winter and summer ranges of forest-tundra woodland caribou in the Hudson Bay Lowlands of northern Ontario.

Serge Couturier: Genetics and condition of three caribou ecotypes in Québec-Labrador

Serge Couturier presented a summary of his recent Ph.D. dissertation research. He studied population genetics, space use and body condition of seven populations of three ecotypes of caribou on the Québec-Labrador Peninsula (Figure 3; Couturier 2007). The montane and migratory ecotypes were genetically more similar to one another than either was to the sedentary ecotype. The two migratory herds were more similar genetically than either was to the four sedentary herds. Two potential gene flow mechanisms in the migratory ecotype were quantified for the first time: rutting range overlap and infidelity to calving grounds. It seems that body condition (calf body mass and adult body size and reserves) decreased during growth of the Rivière-George herd and later slightly improved during the population decline, consistent with density-dependent resource limitation. Body condition of caribou from the Rivière-aux-Feuilles herd decreased during demographic growth and is now lower than for caribou of the George herd. Movements and body size differed among the three ecotypes. Migratory caribou are now smaller than sedentary caribou although it was the opposite in the 1960s, probably because density-dependent

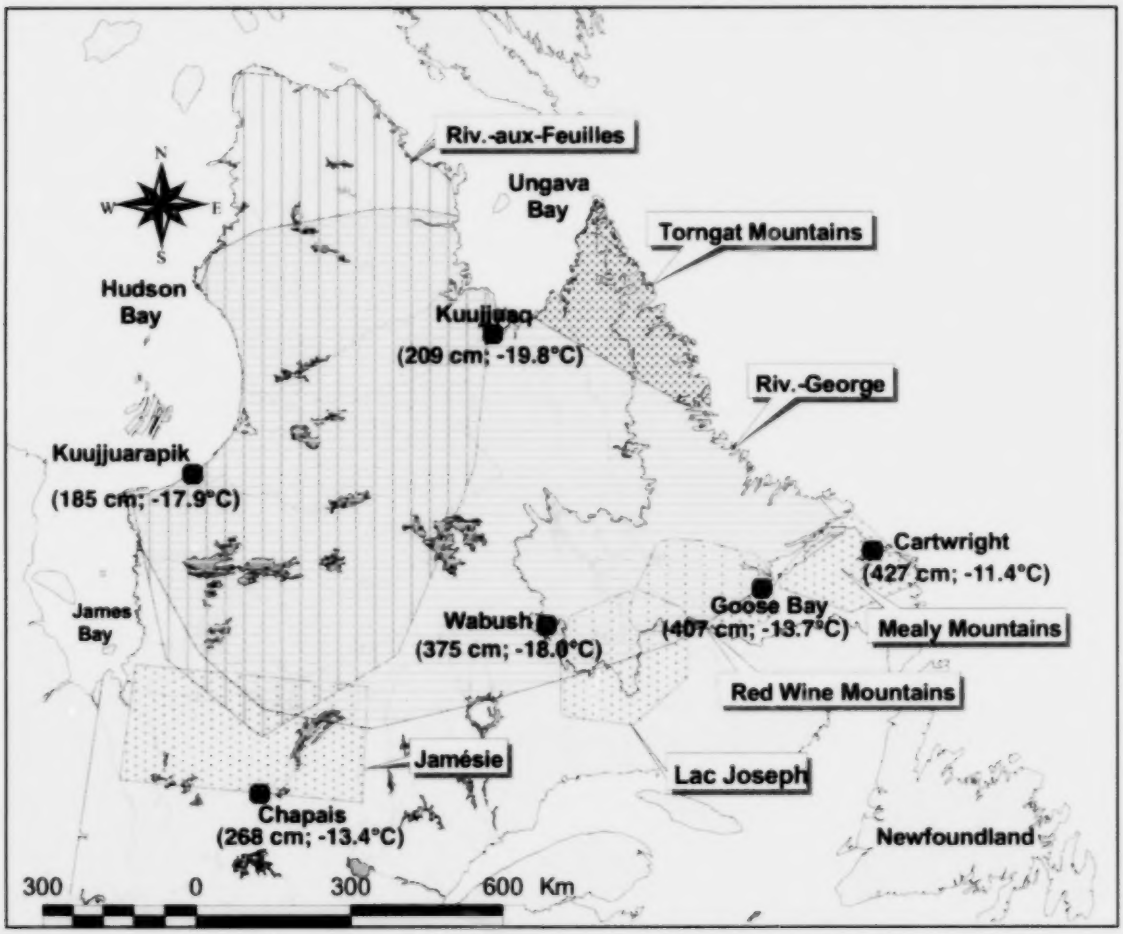


Figure 3. Annual ranges of the migratory Rivière-George caribou herd (horizontal shading, 1991 – 2003), the migratory Rivière-aux-Feuilles herd (vertical shading, 1993 – 2003), four sedentary herds (Lac Joseph, Mealy Mountains, Red Wine Mountains: following Schmelzer et al. 2004; Jamésie: approximate annual range), and the montane Torngat herd (Schaefer and Luttich 1998) in the Québec-Labrador Peninsula (Canada). Snowfall (cm) and daily minimum temperature (°C) averages in winter (November – April) from 1962 to 2002 (data from Environment Canada) are shown under the weather station name.

effects induced a body size reduction in migratory caribou during demographic growth. These temporal variations in body condition of migratory caribou are related to summer habitat quality, but also to climatic factors and to major changes in seasonal and annual movements. Indeed, movements were positively related to population size in both migratory herds. Although it is not known whether the increase in movement is related to density-dependent (e.g., habitat deterioration) or density-independent factors, it is hypothesized that temporal variations in movements represent one of the mechanisms acting over decades on body condition of migratory caribou. Serge found many differences among the three caribou ecotypes which support the use of this concept in conservation. Although the two migratory herds were genetically similar, their body condition and movements were distinct. Thus, it seems justified for conservation and management purposes to distinguish these two populations that are interacting in a metapopulation model; a hypothesis that remains to be tested.

These presentations lead to a question of relatedness between the forest-tundra and the forest-dwelling ecotypes within the far north of Ontario. Is there a pronounced gene flow between these populations, similar to that observed between the migratory and sedentary woodland caribou herds in Québec? Or, are the Ontario forest-tundra and forest-dwelling caribou ecotypes isolated populations? In addition, what is the extent of population substructure within forest-tundra or forest-dwelling caribou in Ontario? These questions need to be addressed as part of a broad research program to understand woodland caribou dynamics and populations in Ontario.

RESEARCH STRATEGY

A research program for forest-dwelling woodland caribou in Ontario must address short-term needs (e.g., synthesis of current/historical data) as well as providing for the long-term goal of estimating the likelihood of caribou persistence under various policy alternatives. To help focus ideas on a research strategy to meet these requirements, six questions were identified:

1. Where are and where were forest-dwelling woodland caribou in Ontario?
2. What is current habitat for forest-dwelling woodland caribou in Ontario?
3. Where is the current habitat for forest-dwelling woodland caribou in Ontario?
4. What factors support or imperil the persistence of forest-dwelling woodland caribou in Ontario?
5. Can factors that support persistence be enhanced and/or factors that imperil persistence be mitigated?
6. Under what range of conditions do forest-dwelling woodland caribou (re)occupy their habitat?

These questions are framed around qualifying caribou occurrence (questions 1 to 3) on the short-term and estimating persistence through a vital rates study (questions 4 to 6) in the longer-term. Consolidating existing data will enable researchers to tackle some of the above questions. For example, the distribution of caribou (question 1) could be addressed by combining existing aerial survey observations and telemetry collaring data. Development of RSF models from consolidated occurrence data and habitat variables will contribute to resolving questions 2 and 3. A detailed experimental design, involving field-based research, to examine the factors and generate PVA models is required to address questions 4, 5, and 6.

To address short-term requirements (questions 1 to 3) there is a need to delineate populations of forest-dwelling woodland caribou in Ontario. Different policy options (i.e., management strategies) may be necessary to maintain caribou on the landscape depending on whether a population is isolated, discontinuous, or continuous. The issue of population structure can be tackled using a combination of genetic analyses and movement data acquired by GPS collars on caribou. Examples of assessing population ranges or herds based on movement data can be drawn from Manitoba, and Serge Couturier's (2007) work on population genetics in Québec can provide insight into determining the connectivity of populations (Boulet et al. 2007) in Ontario.

Before experiments can be designed to deal with longer-term goals (questions 4 to 6), the scale of

persistence needs to be defined. Clearly, it is not possible to experimentally evaluate probability of persistence at the provincial level because there is a lack of replication at that large scale (i.e., the sample size is $n = 1$). Consequently, experiments need to be planned at a fairly coarse regional scale (i.e., sub-population level) with as much replication as possible across the province; once again taking into consideration whether a population is isolated, discontinuous, or continuous.

Based on the foregoing, a research program for forest-dwelling woodland caribou in Ontario will initially require two separate study designs: one for the analysis of historic occurrence data and another for the estimation of persistence. This is consistent with previous discussions that suggested historical occurrence data be used to develop RSFs as an aid in the design of vital rate studies to generate PVA models and better understand caribou persistence under various policy options. It is also apparent that complementary studies (e.g., genetics) will be required and these additional research projects need to be identified as soon as possible to ensure coordination and facilitate collaborations among researchers.

RESEARCH DESIGNS

Analysis of Occurrence Data

Over the last several years, the OMNR has made a significant effort to compile all historic woodland caribou occurrence data from ground sightings, aerial surveys, and telemetry studies into a database in the Natural Resources and Values Information System (NRVIS). At present, more recent information (i.e., telemetry data) is already in the database and efforts to enter older data are continuing. Populating the database is time-consuming because a large effort is needed to correct the data and to ensure it meets corporate standards for quality control and assurance. This process should continue at a cautious pace because adequate time is necessary to ensure proper quality control and data standards are met, but certain components could be prioritized for completion to facilitate pressing data requirements for the analysis of historic occurrence data and development of RSF models. The database is available to government and non-government agencies, private sector organizations, and the general public through the Ontario Geospatial Data Exchange (OGDE) provided by Land Information Ontario (LIO).

Since predation (predator density, predation rate, and prey biomass or abundance, including alternative prey) was identified as one of the most important variables in the determination of caribou occurrence, there was consensus on linking the caribou database with other information currently within the province. This would include moose aerial inventories (MAIs), wolf surveys, white-tailed deer data, beaver surveys, and black bear surveys. At present, the moose database is well developed for areas other than the far north, there have been wolf surveys completed in all ecoregions, except the high density area in northwestern Ontario, and there is a good base of black bear hair snare surveys for much of the province, except the far north. The status of the white-tailed deer and beaver survey information could not be ascertained during the workshop but it was acknowledged that these data should be available through the OMNR.

Jim Schaefer (Associate Professor, Trent University), Rob Rempel (Research Scientist, CNFER), Bruce Pond (Research Scientist, WRDS), Glen Brown (Terrestrial Wildlife Analyst, OnTAP), Marty Obbard (Research Scientist, WRDS), Art Rodgers (Research Scientist, CNFER), and Brent Patterson (Research Scientist, WRDS) agreed to work together on a re-examination of previous work (Pearce and Eccles 2004) to develop RSFs using updated historical occurrence data in the provincial database. More specifically, it was decided that separate RSFs would be developed for both the northeast and northwest areas of the province based solely on telemetry data from recent caribou collaring programs in each region. In addition to roads, predation, and multi-scale habitat pattern, weather data, particularly snow depth, will be included in these RSF models. As far as possible, habitat variables will be used that match those in forest projection models (e.g., PatchWorks). The scale of these analyses is likely limited to 100 km^2 by the availability of data for some variables.

To better understand the connectivity of caribou sub-populations in Ontario, John Fryxell (Professor,

University of Guelph) and Tom Nudds (Professor, University of Guelph) agreed to pursue movement studies and work with Paul Wilson (Assistant Professor, Trent University) to develop a protocol to identify whether and to what extent woodland caribou are spatially subdivided into local populations, perhaps operationally defined as the probability of immigration/emigration of individuals among groups at different scales of spatial resolution. For this work, they would use telemetry data in the provincial database and results of ongoing genetics studies.

As a further guide to the design of vital rate studies and to identify information gaps in the development of PVA models, telemetry data in the provincial database will also be used to estimate spatial and temporal variation in important demographic parameters (primarily calving rates and mortality) of caribou populations in Ontario. This work, led by John Fryxell (Professor, University of Guelph), has been initiated through the Forest Ecosystem Science Co-operative 10th Anniversary Fund and Environment Canada Species at Risk Fund in Ontario.

Estimation of Persistence

Since the probability of caribou persistence is primarily influenced by the same factors that contribute to their pattern of occurrence (i.e., roads, predation, multi-scale habitat pattern and condition), the general word model/hypothesis to be used in the development of a research project to estimate persistence is: ***the probability of forest-dwelling woodland caribou persistence = f (roads [density/use/type] + predation [density/rate/prey biomass or abundance] + multi-scale habitat pattern and condition)***. Competing models derived from this general word model/hypothesis are similar to those developed during the first CNFER Research Workshop (Rodgers et al. 2007), where "probability of occurrence" is replaced with "probability of persistence". To estimate probability of persistence, the effects of key uncertainties on population vital rates (i.e., mortality/survival, reproduction, immigration, emigration) must be determined. This needs to be done in the context of policy options, particularly those related to determinants of multi-scale habitat pattern (e.g., landscape disturbances created by commercial forestry operations, fire suppression, road placement, ungulate harvest management), to determine potential effects on caribou extinction risk. These objectives can be met through consideration of 4 – 6 "treatments" representing sharp contrasts among the key drivers in the system (Table 3).

Whereas the "Control", Treatment 1, and Treatment 2 may be examined in existing areas, such as parks and protected areas and extant Forest Management Areas (FMAs), provisions may need to be made through alternative policy options to establish the remaining treatments. For example, total prey density may be reduced in an existing FMA to meet the requirements of Treatment 3 by increasing hunting (i.e., moose, white-tailed deer) and trapping (i.e., beaver) opportunities on alternate prey. Total food biomass for black bears might also be reduced by herbicide spraying of berry plants (e.g., *Vaccinium* spp., *Rubus* spp.). The reciprocal, Treatment 5, could be achieved with reduced hunting and trapping opportunities on alternate prey and reduced herbicide application in an existing FMA. Treatment 5 was suggested because the short term response of predators to reduced total prey density, as provided by Treatment 3, may be to increase the risk to caribou. Similar to Treatment 3, implementation of Treatment 4 in an existing FMA would require increased hunting (i.e., of black bears) and trapping

Table 3. Treatments to assess the relative effects of key uncertainties on vital rates hypothesized to determine the persistence of forest-dwelling woodland caribou in Ontario.

	Habitat regime	Prey density	Predator density	Roads
"Control"	Un-logged	Un-manipulated	Un-manipulated	None
Treatment 1	Logged	Un-manipulated	Un-manipulated	Un-manipulated
Treatment 2	Logged	Un-manipulated	Un-manipulated	No Road Access
Treatment 3	Logged	Reduced	Un-manipulated	Un-manipulated
Treatment 4	Logged	Un-manipulated	Reduced	Un-manipulated
Treatment 5	Logged	Increased	Un-manipulated	Un-manipulated

(i.e., of wolves) opportunities, but on predators. Treatment 5 is also a variant of Treatment 4, such that both 4 and 5 have higher levels of prey in relation to predator density, but different functional and numerical responses by caribou might be expected.

The study design outlined above does not specifically examine the effects of different forest harvesting methods, such as partial cutting methods, on caribou persistence. Whereas traditional harvesting methods (i.e., clear cutting) tend to draw alternate prey, particularly moose, into caribou areas, which in turn encourages predators, it may be worth exploring the effects of partial cutting systems, especially in spruce dominated forests, on the density/abundance of moose and predators. It will also be necessary to investigate the effectiveness of post-harvest silviculture in minimizing attractiveness of harvest areas for moose and/or deer. Information on different silvicultural treatments in different parts of the province (i.e., northeast vs. northwest) should be explored for potential alternatives. As well, the current project design does not address how forest harvesting might occur while ensuring caribou remain within harvested areas. The effect of logging in proximity to refuge habitat on successful caribou calving was also suggested as an important topic for research. Because of the time lag expected between timber harvesting and any effects on caribou, treatments involving direct habitat manipulation by different forest harvesting methods should be undertaken as soon as possible.

Although the treatments proposed in the study design (Table 3) may reveal the conditions needed to support the persistence of forest-dwelling woodland caribou in Ontario, these manipulations do not necessarily identify the conditions needed for caribou to reoccupy an area. It was suggested that a translocation experiment could be undertaken to determine whether caribou will reoccupy an area. However, the results of a translocation study may be difficult to interpret. For example, it is conceivable that traditional use of some areas may be so strong that caribou may not move into rehabilitated habitat when it becomes available / accessible. Moreover, we do not currently have sufficient knowledge of the conditions needed to support the persistence of forest-dwelling woodland caribou in Ontario, so identification of suitable areas for translocations would need to rely on expert opinion and may have limited success. It would be better to first undertake vital rates studies to generate PVA models and better understand caribou persistence then apply that knowledge in the form of translocations. This approach will increase the likelihood of successful reintroductions and will provide another opportunity to evaluate the performance of PVA models in predicting caribou persistence throughout the province.

A number of general considerations related to assessment of the independent variables in the study were identified and discussed:

Roads: This variable includes the density of linear corridors (i.e., roads, railways, trails, snowmobile trails, hydro/gas lines), the frequency of use, as well as the seasonality of use.

Predation: This variable includes predation rates by wolves, bears, and harvesting by First Nations (where relevant).

Prey: The influence of total prey biomass (i.e., caribou + moose + white-tailed deer + beaver) and individual prey biomass (i.e., caribou, moose, white-tailed deer, or beaver) on wolf distribution and abundance needs to be assessed. The influence of total prey biomass (i.e., caribou + moose + white-tailed deer + hard mast/berry production) and individual prey biomass (i.e., caribou, moose, white-tailed deer, or hard mast/ berries) on bear distribution and abundance also needs to be assessed. A cautionary note suggested that an increase in hunting and trapping used as a method to reduce prey densities (Treatment 3) or predator densities (Treatment 4) may have no effect on prey or predators, depending on the location of the treatment units, because hunters and trappers may not be as enthusiastic to hunt or trap in remote areas occupied by caribou.

Habitat: Habitat will require an assessment of pattern at multiple spatial scales. It includes considerations of seasonal ranges (e.g., winter and calving), edge density and patch sizes, food supply, climate, and habitat requirements of other prey species (i.e., moose, white-tailed deer, beaver) and predators (i.e., wolves, black bears).

These deliberations led to a discussion of what needs to be measured and suggested methods

of measuring the dependent and independent variables in each of the treatment units, as summarized in Tables 4 – 8. Attributes of potential study areas with regard to achieving contrasts among the key drivers in the system, and sufficient replication of measurements associated with the dependent and independent variables, were then identified.

Table 4. Caribou measurements within each treatment unit.

CARIBOU		
Category	**What to measure**	**How to measure it**
Vital Rates	Cause specific mortality	GPS tracking
	Age specific mortality	GPS tracking
	Age of first calving	GPS tracking/direct observations
	Parturition and recruitment	GPS tracking/direct observations
	Natal dispersal	GPS tracking/GIS analysis
	Pregnancy rate	Progesterone assay of faecal samples
General	Age	Teeth wearing - collaring
	Morphometrics	Capture and handle animal
	Body condition	Back fat analysis or bone marrow
	Stress	Blood serum (hormones) at capture
Movement	Genetic movement	Genetic analysis-blood/tissue at capture
	Movement trajectories	GPS/GIS analysis
Diet/Nutrition	Seasonal diet composition	Stable isotope from fecal sample
Parasites	*P. tenuis* infection	Blood serum assay
	Parasite densities in ungulates	Baermann funnel analysis of faecal pellets (for larvae) or examination (for eggs) of pellets of all ungulate species residing in the area

Table 5. Habitat or landscape characteristics to measure within each treatment unit.

HABITAT OR LANDSCAPE CHARACTERISTICS		
Category	**What to measure**	**How to measure it**
Landscape Metrics[1]	Fire disturbance	GIS using FRI or satellite imagery
	Edge density	GIS using FRI or satellite imagery
	Linear features (see Table 8)	GIS using FRI or satellite imagery
	Proportion of large lakes for escape	GIS using FRI or satellite imagery
	Proportion of each forest type/age	GIS using FRI or satellite imagery
	Logged and un-logged areas	GIS using FRI or satellite imagery
	Refuge areas / calving sites	GIS using FRI or satellite imagery
	Connectivity	GIS using FRI or satellite imagery
Environmental	Snow depth & hardness	Precipitation model or MNR regional snow survey
	Other weather data	Climate model or Environment Canada
Food Availability	Shrub/browse/lichen density	GPS/GIS for identifying core areas. Field studies for determining shrub/browse densities.
	Other ungulate density	Aerial moose/deer inventory. Pellet samples.
Human Disturbances	Outfitter camps	Local knowledge and GIS
	Shore lunch sites	Local knowledge and MNR resources
	Campsites	Local knowledge and Crown Land Use
	Snowmobile routes	Local knowledge and MNR resources
	Hiking trails	Local knowledge and MNR resources
	Trap lines	Registered trap line maps and filed returns
Other	Line of sight	Shrub density

[1]Landscape metrics will be measured at multiple spatial scales.

Table 6. Predator measurements within each treatment unit.

PREDATORS		
Category	**What to measure**	**How to measure it**
Bears	Bear density	Bear snare and DNA analysis
	Bear distribution	Bear snare and DNA analysis
	Bear distribution in relation to forest harvesting	GPS collar/GIS analysis
	Diet composition	Stable isotope analysis
Wolves	Wolf density	GPS collars on α & β wolves of each pack
	Pack size	GPS collars on α & β wolves of each pack
	Movements	GPS collars on α & β wolves of each pack
	Kill rate	GPS collars on caribou
	Extent and pattern of wolf harvest	Trap lines & mandatory hunter surveys
	Territory size/range	GPS collars on α & β wolves of each pack
	Diet composition	Stable isotope analysis

Table 7. Alternate prey measurements within each treatment unit.

PREY		
Category	**What to measure**	**How to measure it**
Beaver	Beaver density	Aerial survey
Deer	Deer density	Pellet/track/hunter surveys
Moose	Moose density	Aerial inventory
Prey Interactions	Total prey biomass	Estimated from beaver/moose/deer densities
	Relative distribution of moose/caribou/deer/ beaver (prey segregation)	GIS analysis

Table 8. Linear feature measurements within each treatment unit.

LINEAR FEATURES		
Category	**What to measure**	**How to measure it**
Roads	Road density and type	GIS/ satellite imagery
	Road use intensity	Local knowledge & traffic counter
Railways	Railway density	GIS/ satellite imagery
	Railway use intensity	Local knowledge & railway company
Snowmobile Routes	Snowmobile route density	Local knowledge and MNR resources
	Snowmobile route use intensity	Local knowledge & traffic counter
Trails	Trail density	Local knowledge and MNR resources
Hydro/gas lines	Line density	GIS/ satellite imagery

Given the current distribution of forest-dwelling woodland caribou in the province, prospective study areas should be distributed east – west along the northern extent of forestry operations (Area of the Undertaking – AOU). Differences in caribou population densities and ecoregional differences in habitat will require treatment areas in both the northeast and northwest regions. Sites should not be located too far north otherwise a biological productivity gradient will be introduced to the system. On the other hand, due to the potential importance of connectivity between forest-dwelling and forest-tundra caribou ecotypes, it may be necessary to situate some study sites further north, where these interactions can be assessed. The "Control" treatment area may be situated in and around one of northwestern Ontario's large Provincial Parks (i.e., Wabakimi or Woodland

Caribou Provincial Parks), as this treatment cannot have current timber harvesting (Table 3). All treatment units will need a low proportion of young forest and a high proportion of forest that is > 40 years of age, and relative proportions of these forest ages should be similar among sites. The northeast side of Lake Winnipeg (in Manitoba) or western Québec are candidates for study sites where inter-provincial cooperation is feasible. The size of each treatment unit must be sufficient to support a population of about 200 – 400 woodland caribou. Depending on caribou population density, such an area is likely on the order of 5,000 – 10,000 km^2. Treatment units should be non-contiguous, where the minimum distance between units is based on a small multiple (e.g., 3 to 5) of the average home range size or the average annual dispersal distance of individual caribou. Average dispersal of woodland caribou within Ontario was suggested to range from 10 to 50 km (for females), so a conservative distance between treatments might be ≥ 50km.

Additional criteria that need to be taken into account when identifying potential study areas include:

- Densities of alternative prey species (i.e., moose, white-tailed deer, and beaver)
- Densities of wolves and bears
- Presence / absence of timber harvesting and type of silvicultural system in use
- FRI, LandSat, and digital road network data availability
- Landscape considerations including vegetation, fire history, surficial geology, and soils
- Logistic feasibility (e.g., proximity to aviation base, field camps, fuel sources, grocery stores, etc.)
- Proximity to communities willing to participate in population manipulation through reduced / increased hunting and trapping permits on predator and alternate prey species

The availability of historical and current information on any of the above criteria may also prove to be important in selecting treatment units.

Throughout these discussions, the need to involve stakeholders and First Nations during the study design process was emphasized. To some extent this concern was already addressed through the initial caribou research survey wherein stakeholders were invited to identify the most important caribou research issues and comment on the possibility of different research projects. Nonetheless, ongoing involvement of stakeholders and First Nations will be necessary throughout the development and implementation of field studies. The program should be designed with a suite of possible policy outcomes in mind. This will help stakeholders and First Nations evaluate the policy outcomes and further refine the research designs.

RESEARCH FRAMEWORK

As evidenced throughout the CNFER Experimental Design Workshop, and summarized in this report, a research program for forest-dwelling woodland caribou in Ontario, to address short-term management needs and to achieve the long-term goal of estimating the likelihood of caribou persistence under various policy alternatives, will require a suite of complementary research projects with numerous opportunities for collaboration. This would likely include inter-provincial cooperation among researchers in Ontario, Manitoba, and Québec. These projects and potential collaborations need to be identified as soon as possible to ensure coordination through the development of a research framework. Moreover, a single clear account of how these projects all fit together needs to be developed. To provide further coordination and support to such a comprehensive research program, an advisory committee was also recommended. This committee should be open to both workshop participants and individuals not present at either of the CNFER workshops, and would be ideal for those who cannot commit to projects at a ground level but who would like to provide advice and support to the program. CNFER would continue to play an organizational role by providing resources and support for conference calls, additional workshops, etc. To begin development of the caribou research framework for Ontario, a writing team was formed that includes: Jim Baker (Science Business Coordinator, OMNR Applied Research and Development Branch), John Fryxell (Professor, University of Guelph), Brent Patterson (Research

Scientist, WRDS), Art Rodgers (Research Scientist, CNFER), and Ian Thompson (Research Scientist, Canadian Forest Service). The primary task of the writing team will be to take the findings of the CNFER workshops and prepare a broad program proposal for woodland caribou research in Ontario that will outline the range of projects needed to inform a long-term adaptive management approach to caribou conservation. Subsequently, individual groups of researchers could contribute specific project proposals for integration to the overall program. This broad proposal may then be used as a "front end" for smaller project proposals when submitted to various funding sources.

NEXT STEPS

Emphasis will be placed on completing the broad research program proposal, which will include the design of vital rates studies to generate PVA models and better understand caribou persistence under various policy options, as well as complementary studies identified in the CNFER workshops. A draft of the broad program proposal was developed by the writing team between the time of the CNFER Experimental Design Workshop and publication of this report and has been revised several times; most recently to integrate the various research and monitoring pieces in the AOU and Far North (i.e., the area of Ontario north of the AOU). Other steps that need to be undertaken include completion of the provincial caribou database in NRVIS, identifying potential study sites, deciding which treatment unit should occur where, costing out the program, and identifying funding sources, and partners. A more detailed list of next steps is given in Table 9. Data sharing agreements were not fully discussed at the workshop and this topic needs to be revisited and commented on by all research partners before the program moves ahead.

As recognized in the first CNFER workshop, an adaptive management program for woodland caribou in Ontario will be a major logistical undertaking, both administratively and financially. Whereas significant progress was made on the administrative organization of the program during the CNFER Experimental Design Workshop, funding remains a challenge. To leverage financial support for the program, CNFER and other project leaders will pursue funding opportunities through provincial and federal government programs and

Table 9. Next steps in the development of a research program for woodland caribou in Ontario.

Next Step	Description
Research Program Proposal	• Complete broad research program proposal, including vital rates studies to generate PVA models
	• Complete related project proposals and integrate with broad program proposal
	• Complete a looking outward exercise to integrate all proposal components within the broad program to identify gaps and linkages
	• Identify and formalize inter-provincial partnerships with Manitoba and Québec
Data	• Complete the provincial caribou database
	• Link the caribou database to related databases (e.g., moose aerial inventory surveys)
	• Develop some form of data sharing agreement or memorandum of understanding among research partners
Study Areas	• Identify potential study areas and assign possible treatment units
Funding	• Cost the program
	• Strategize the request(s) for funding
	• Assemble a list of all potential partners who may wish to contribute financially (or in kind support) to the program
	• Assemble a list of possible funding sources at the provincial, federal (e.g., NSERC, Environment Canada), and global levels (e.g., World Wildlife Fund, National Geographic Society, etc.)

partners such as industry and non-government organizations (e.g., Forest Ecosystem Science Co-operative, NSERC, World Wildlife Fund, National Geographic Society, etc.).

It is expected that clarification of uncertainties around caribou persistence resulting from this research program will inform revisions and/or modifications to forest management practices and wildlife management policy (i.e., *Crown Forest Sustainability Act*, *Landscape Guide* and *Stand and Site Guide* for forest management planning, *Cervid Ecological Management Framework*) to meet the objective of keeping forest-dwelling woodland caribou on the Ontario landscape. This research program will also make a significant contribution to the attainment of many of the recovery objectives for woodland caribou in Ontario as set out in the *Draft Recovery Strategy for Forest-Dwelling Woodland Caribou (*Rangifer tarandus caribou*) in Ontario* (Ontario Woodland Caribou Recovery Team 2005) and will provide a basis for the refinement of habitat regulations and management plans pursuant to the recovery strategy, as required by the *Endangered Species Act* (LAO 2007;Sections 55 and 11, respectively).

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APPENDIX

CNFER Forest-Dwelling Woodland Caribou Experimental Design Workshop Participants.

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